ASTER 20th Anniversary: Geologic Contributions to Mineral Exploration and Lithologic Mapping

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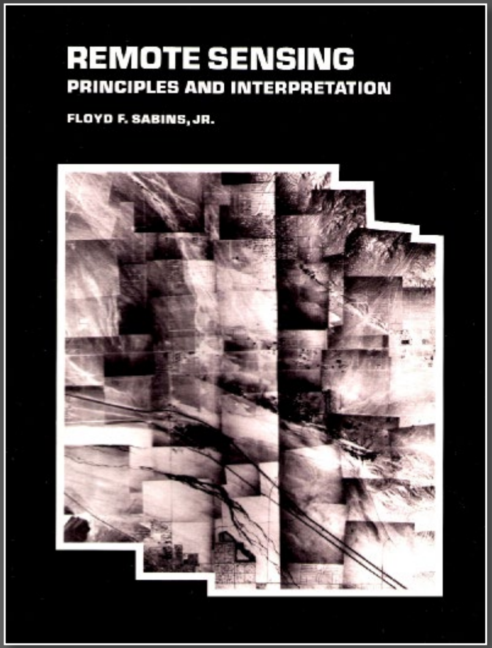
Yokohama, Japan (July 29-Aug 2, 2019)

Setting the Stage -- 1978

***First Textbook*: *Remote Sensing: Principles and Interpretation*,** (Sabins, 1978)



Landsat Color Ratio Composite Goldfield, Nevada Courtesy L.C. Rowan USGS/JPL

During 37 years with Chevron, Dr. Sabins:

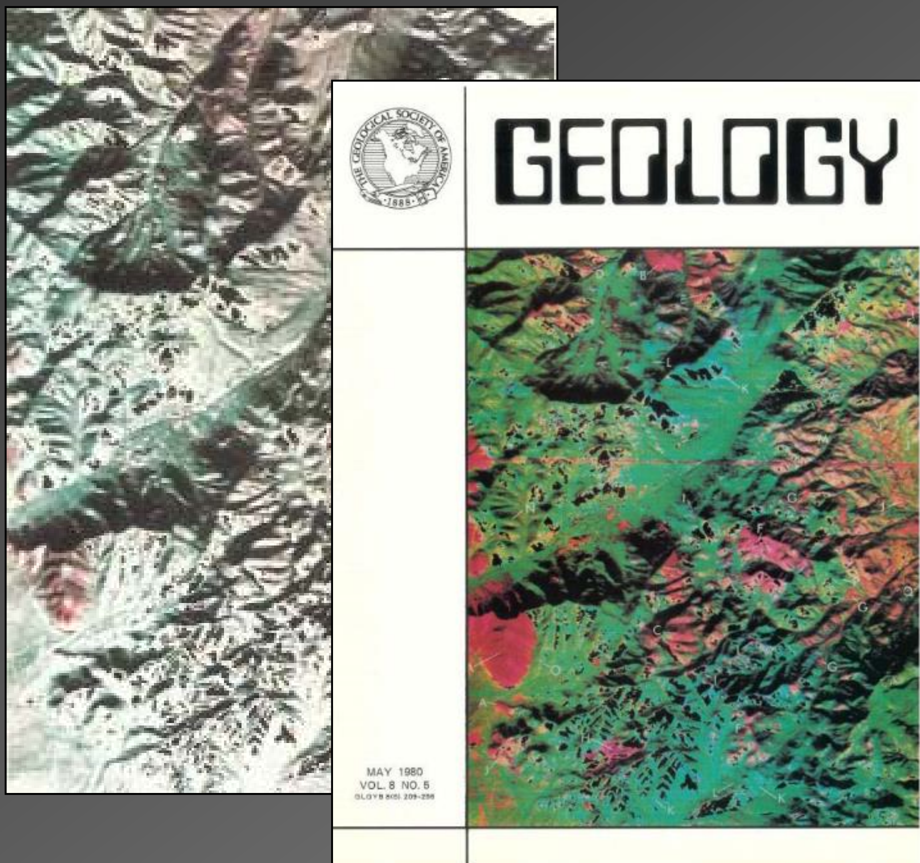
- introduced remote sensing to Chevron leading to the first **oil discoveries in Sudan and Papua New Guinea**
- his programs for digitally processing Landsat images ***discovered the world-class Collahuasi and Ujina, Chile copper deposits,*** earning him the coveted Chevron Chairman's Award

Setting the Stage – 1980s

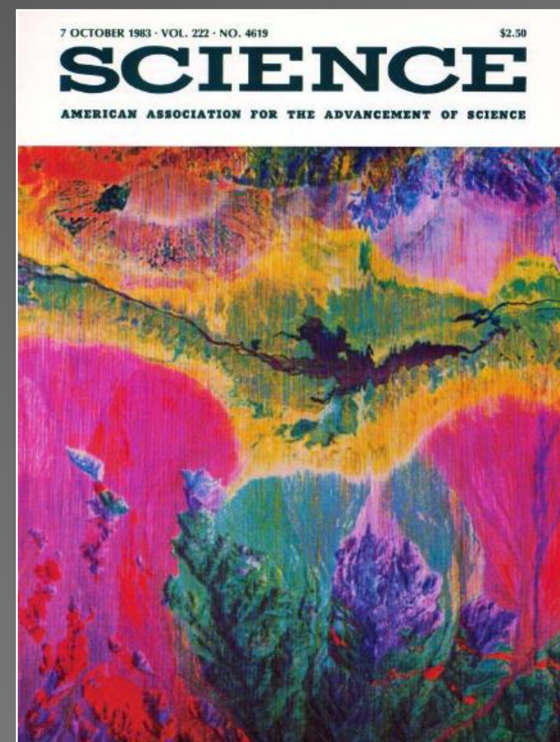
Thermal Infrared Scanning:

- **Thermal Infrared Multispectral Scanner** (TIMS)

Anne Kahle



Kahle and Rowan,1980

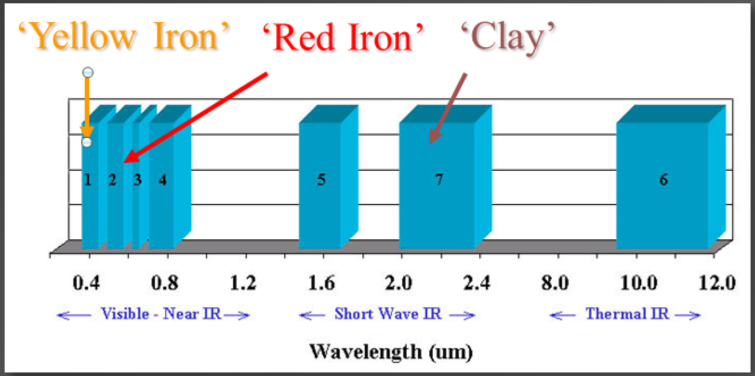


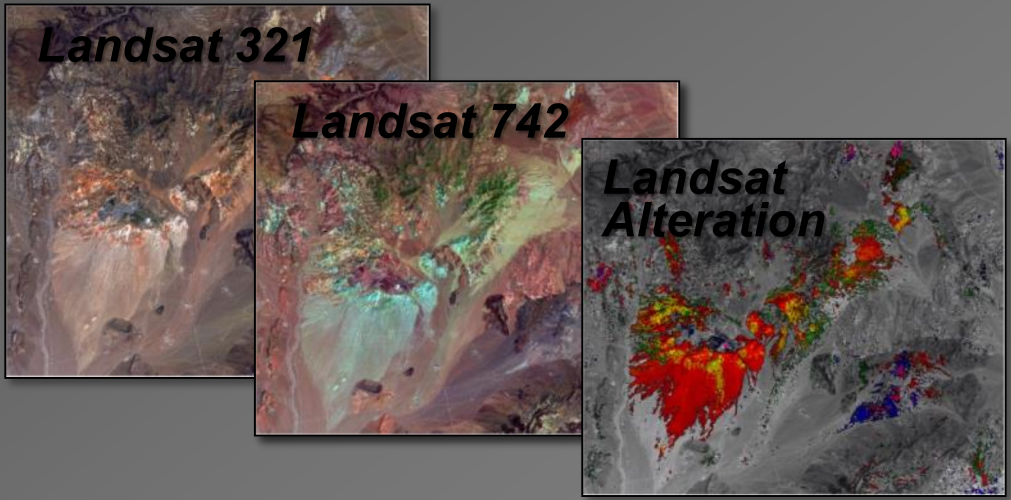
Kahle and Goetz,1983

Setting the Stage – 1970s-1990s

The Satellites:

- **Landsat-1** 1972 (ERTS) with 4 image bands in the VNIR
- **Landsat 4 - Thematic Mapper**, launched July 1982, first to have Band 7 ‘Clay’ band

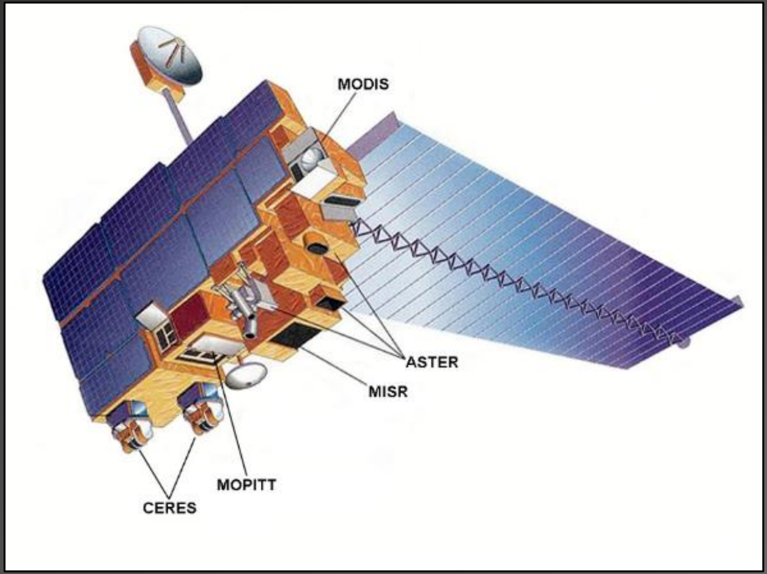




- **JERS-1 OPS** 1992-1998 with 4 image bands in the SWIR

1999-Important Year

- **ASTER** (Advanced Spaceborne Thermal Emission and Reflection Radiometer) launches in December, 1999



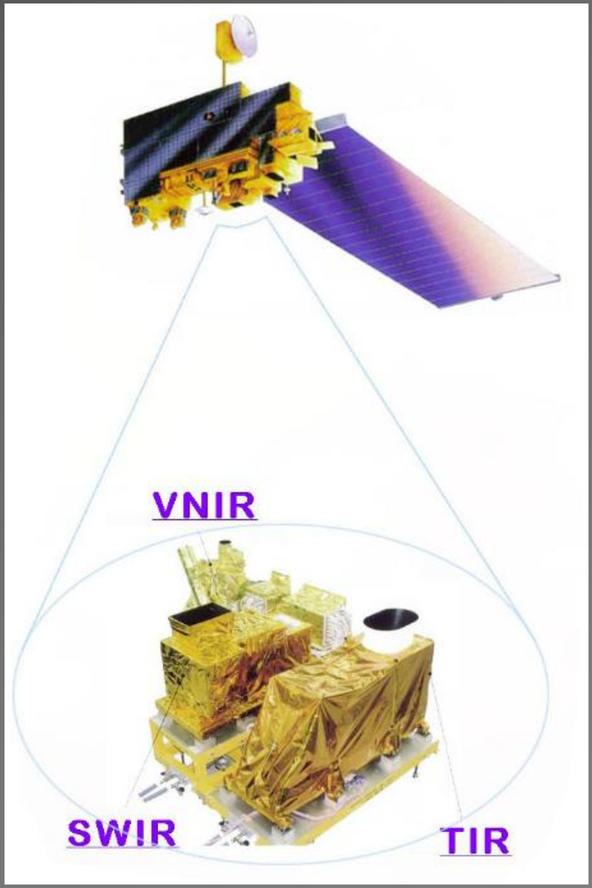
ASTER – Escondida Mine, Chile
Courtesy NASA/Japan Space Systems

- **Landsat 7 ETM+** launches April, 1999 primary advance was the 15m pan band

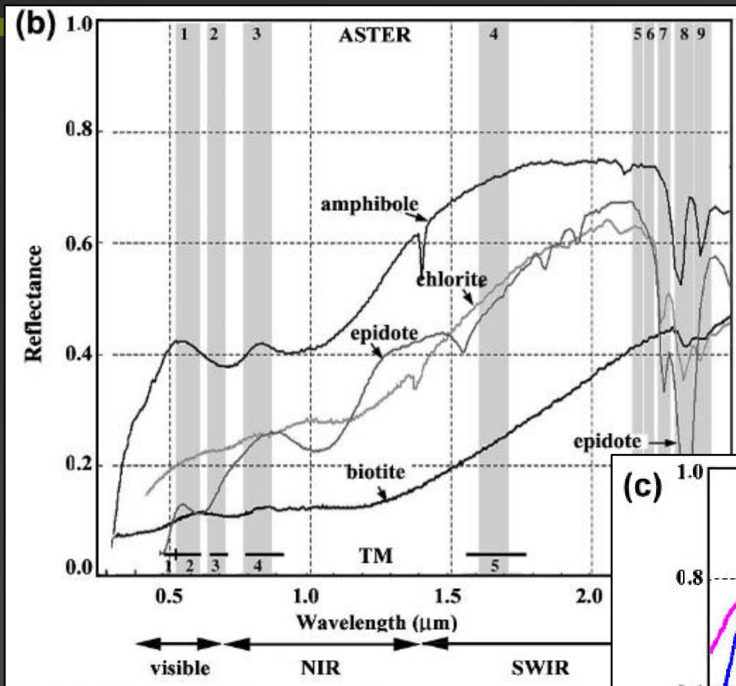
Landsat 7

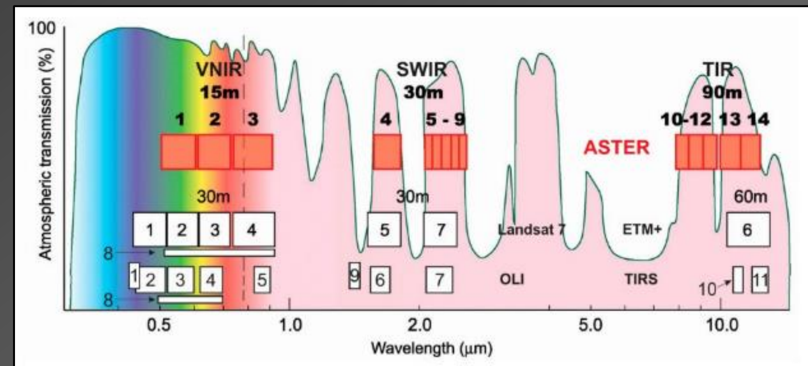
ASTER Instrument

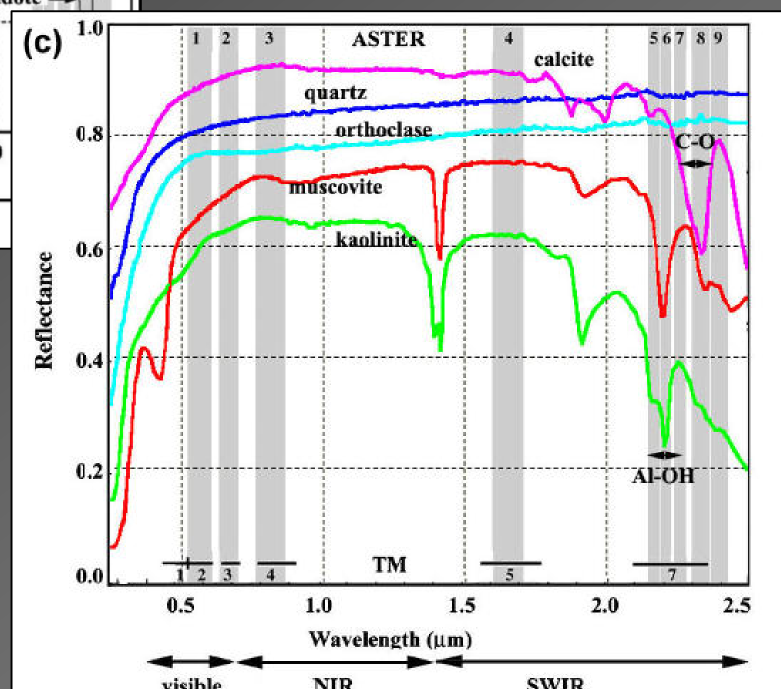
- Launched in December 1999 on Terra Platform
- Joint project of U.S. NASA and Japan Ministry of Economy, Trade, and Industry; follow-on to JERS-1 OPS
- Wide Spectral Coverage
  14 bands in VNIR, SWIR, TIR
- High Spatial Resolution
  15m to 90m
- Along-Track Stereo Capability
- 60 km Swath Width

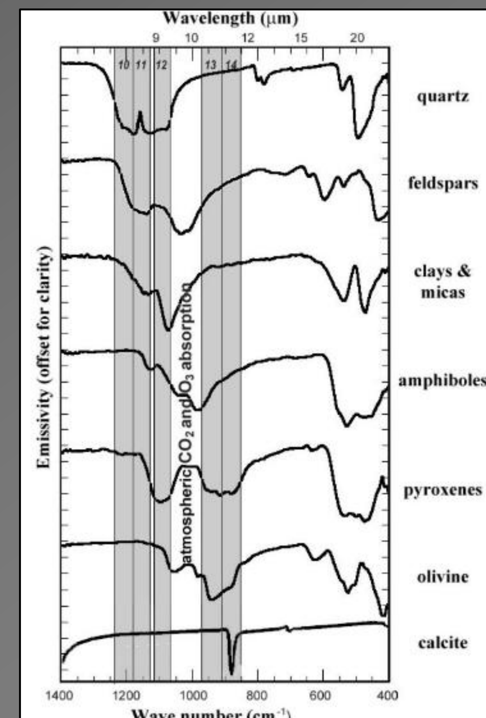


ASTER Bands Designed for Geologic Applications



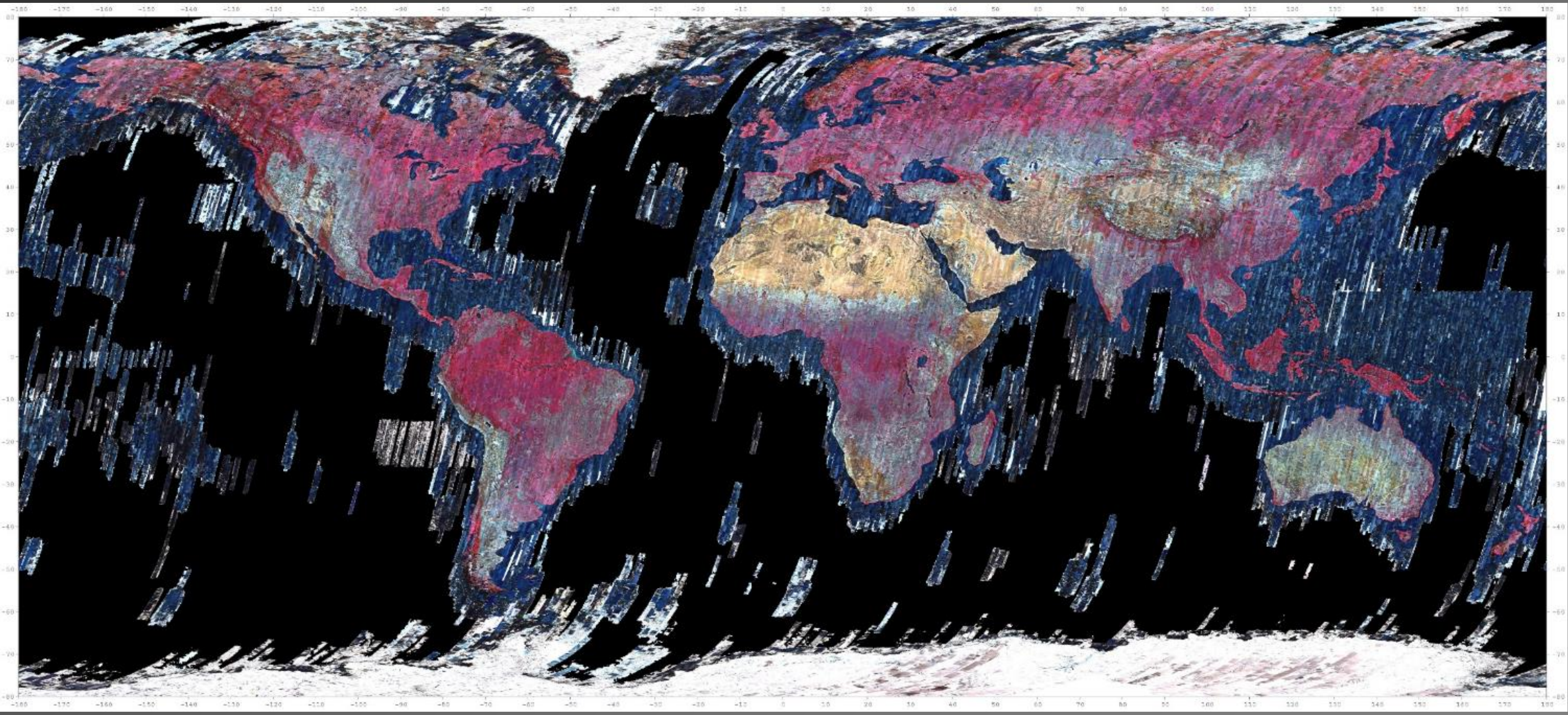




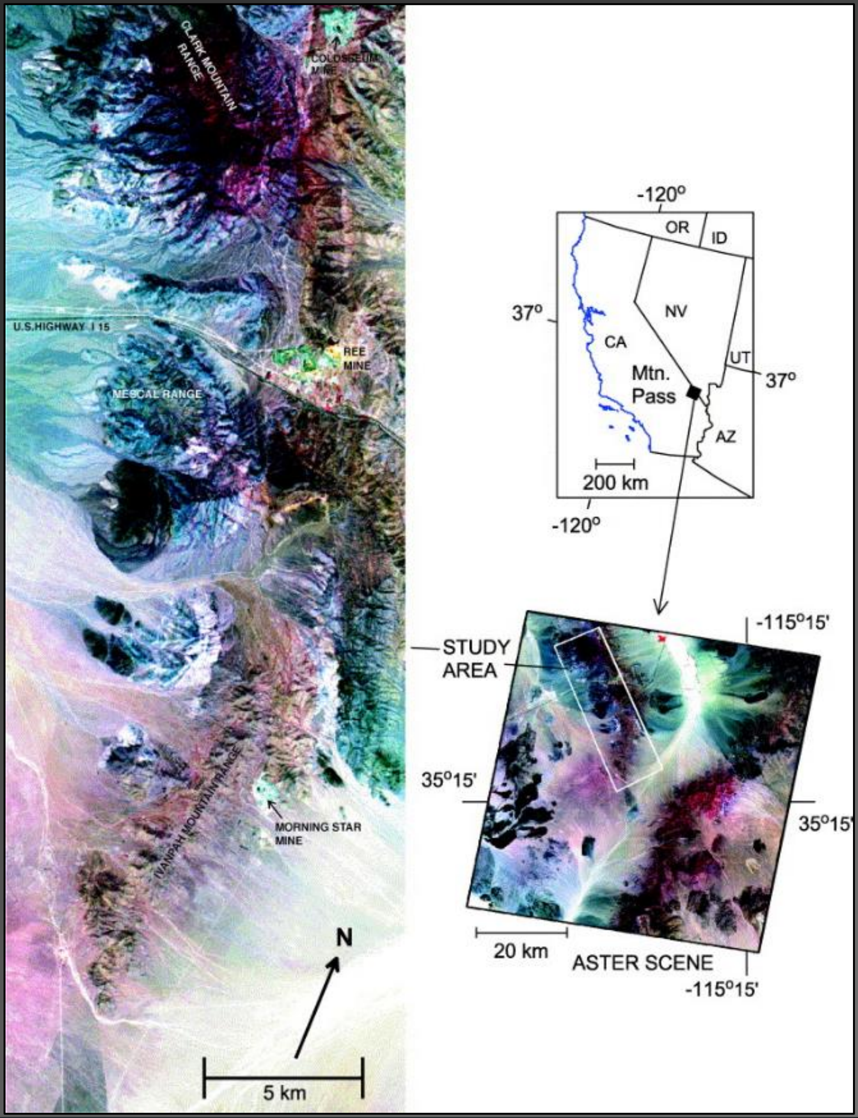


Global Coverage of ASTER Data

More than 3.5 million scenes in archive



Lithologic Mapping

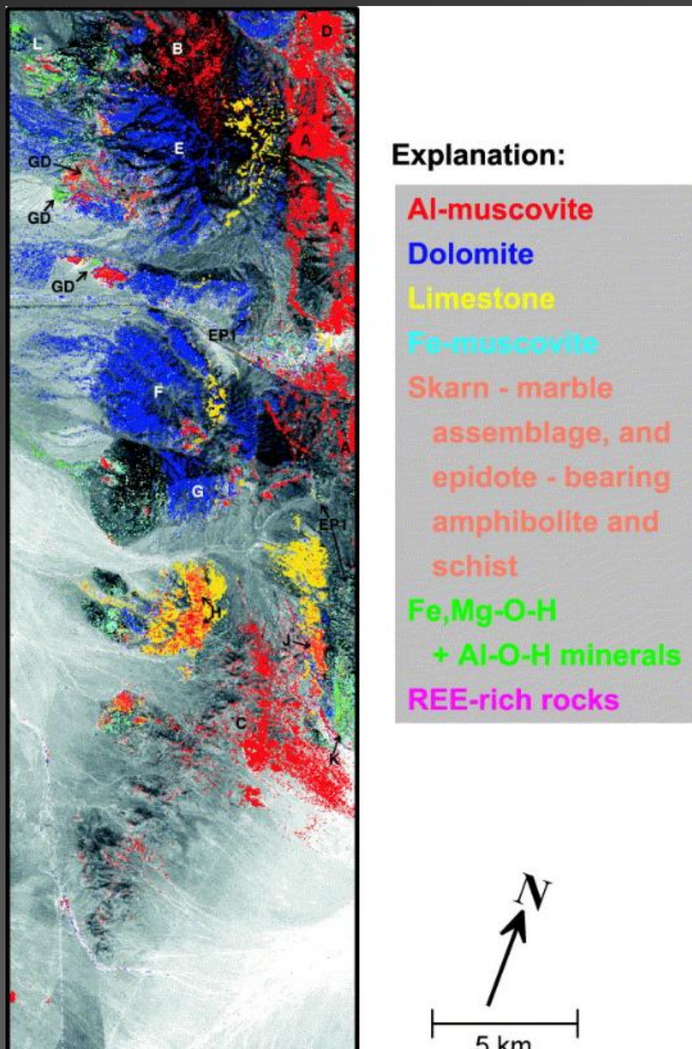


Rowan and Mars (2003) used matched-filter processing and spectral angle mapper processing, after calibrating data using *in situ* spectral reflectance measurements.

The test area (Mountain Pass, CA, USA) exposes quartzose rocks, limestone, dolomite volcanic rocks, granitoids, gneisses, granite, carbonatite, and granodiorite. It is the location of the only REE mine in the US.

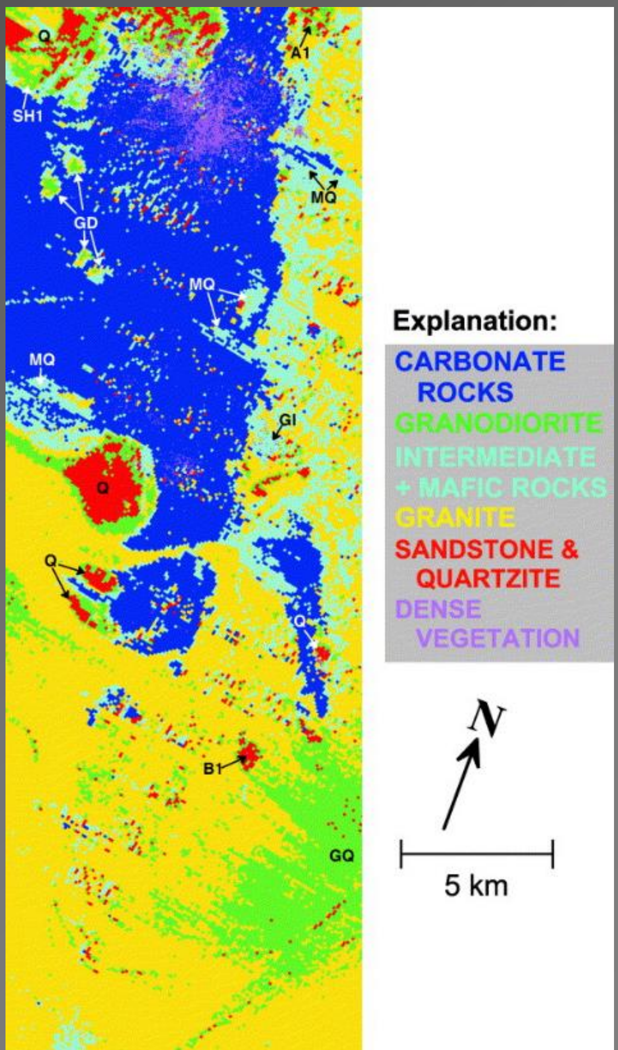
Lithologic Mapping (cont'd)

VNIR + SWIR data



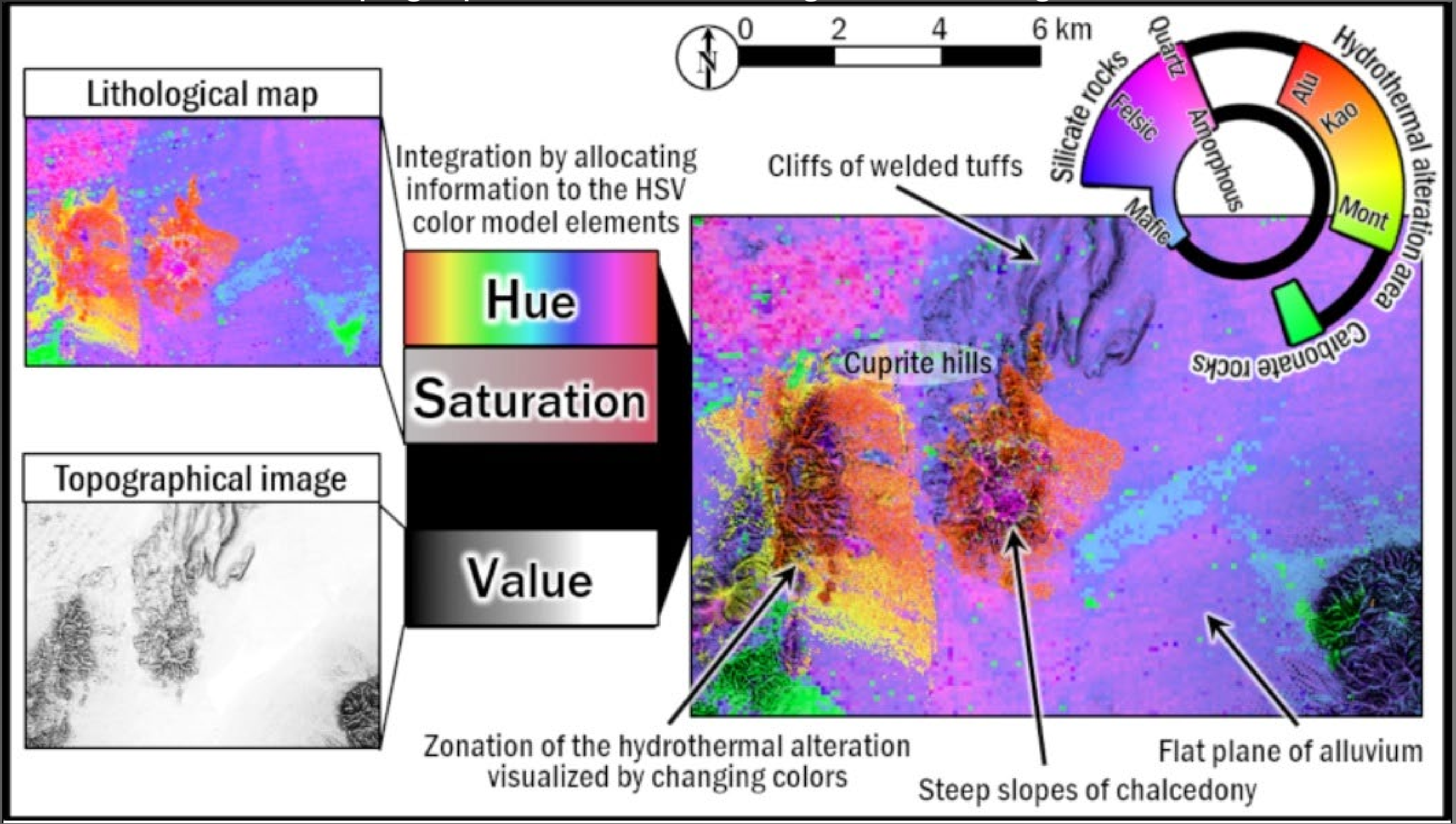
- Calcitic rocks distinguished from dolomitic;
- skarn and marble mapped; Fe-muscovite distinguished from Al-muscovite;
- granitic rocks vs. granodioritic vs. mafic gneiss/amphibolite
- Sandstone and quartzite mapped

TIR data

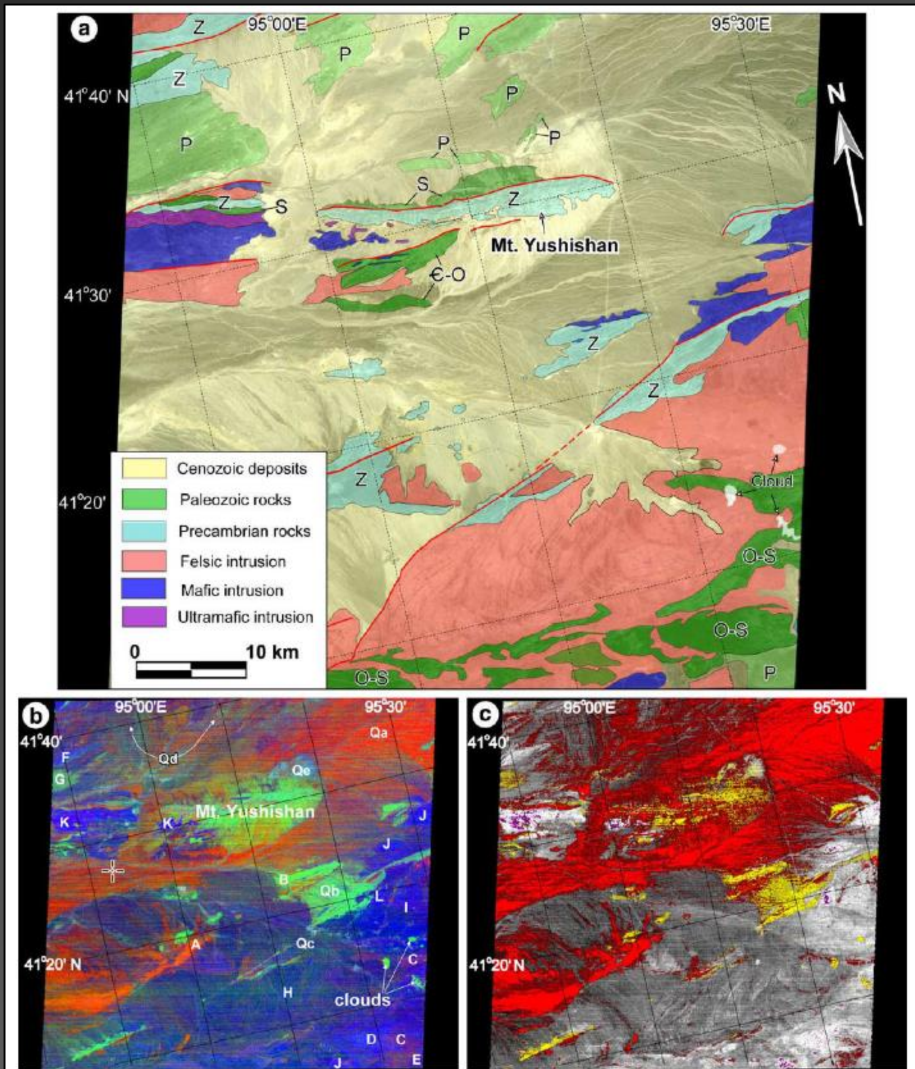


Combining Lithologic Mapping and Topography

Kurata and Yamaguchi (2019) combined and visualized lithologic indices and topographical data in a single color image.



Lithologic Mapping – TIR Indices



Ninomiya et al. (2005) developed quartz (QI), carbonate (CI) and mafic (MI) indices using ASTER TIR data.

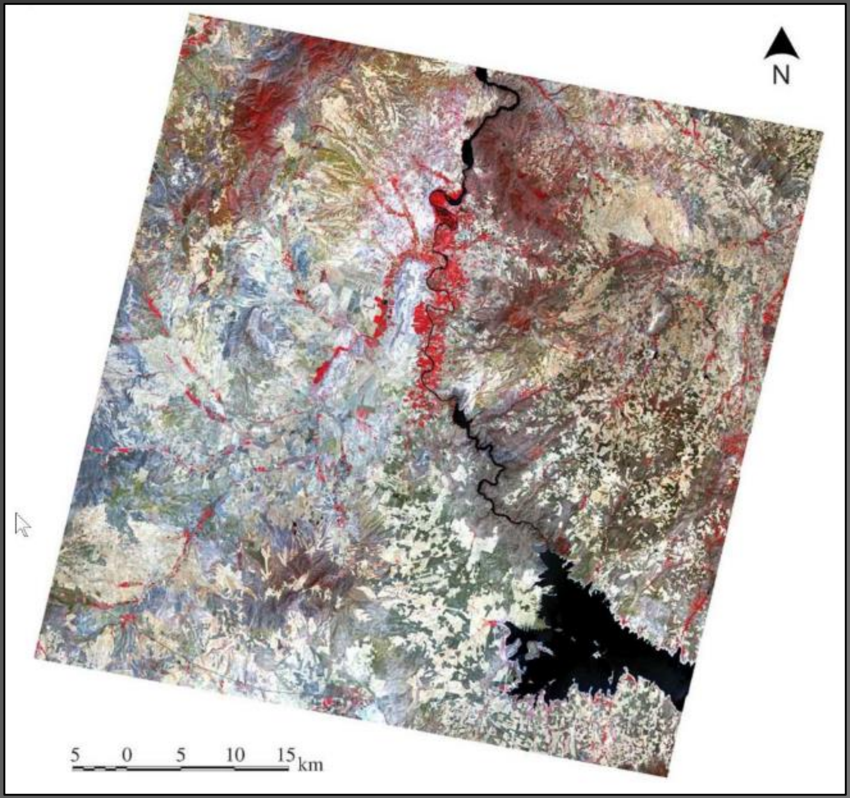
[a] geologic map of study area in China.
[b] RGB composite of QI, CI, and MI indices, respectively.
[c] red = quartzite, dark red = siliceous rocks, yellow = carbonate rocks, dark yellow = possible carbonate rocks, purple = ultramafic rocks.

Many other studies adopted these indices as the analysis contribution for lithologic mapping using the TIR bands with the VNIR and SWIR bands.

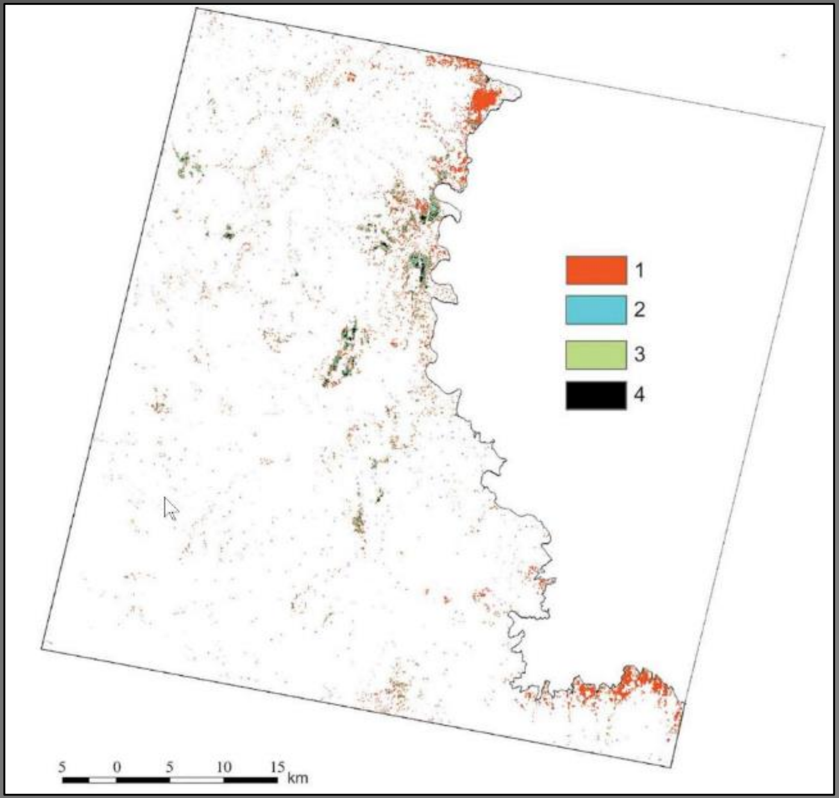
Mapping Gypsum in Turkey

Oztan and Suzen (2011) applied band ratios, decorrelation stretch, principal components, and thermal indices to map gypsum in Turkey. All four methods yielded partial success. Combining all four gave best results.

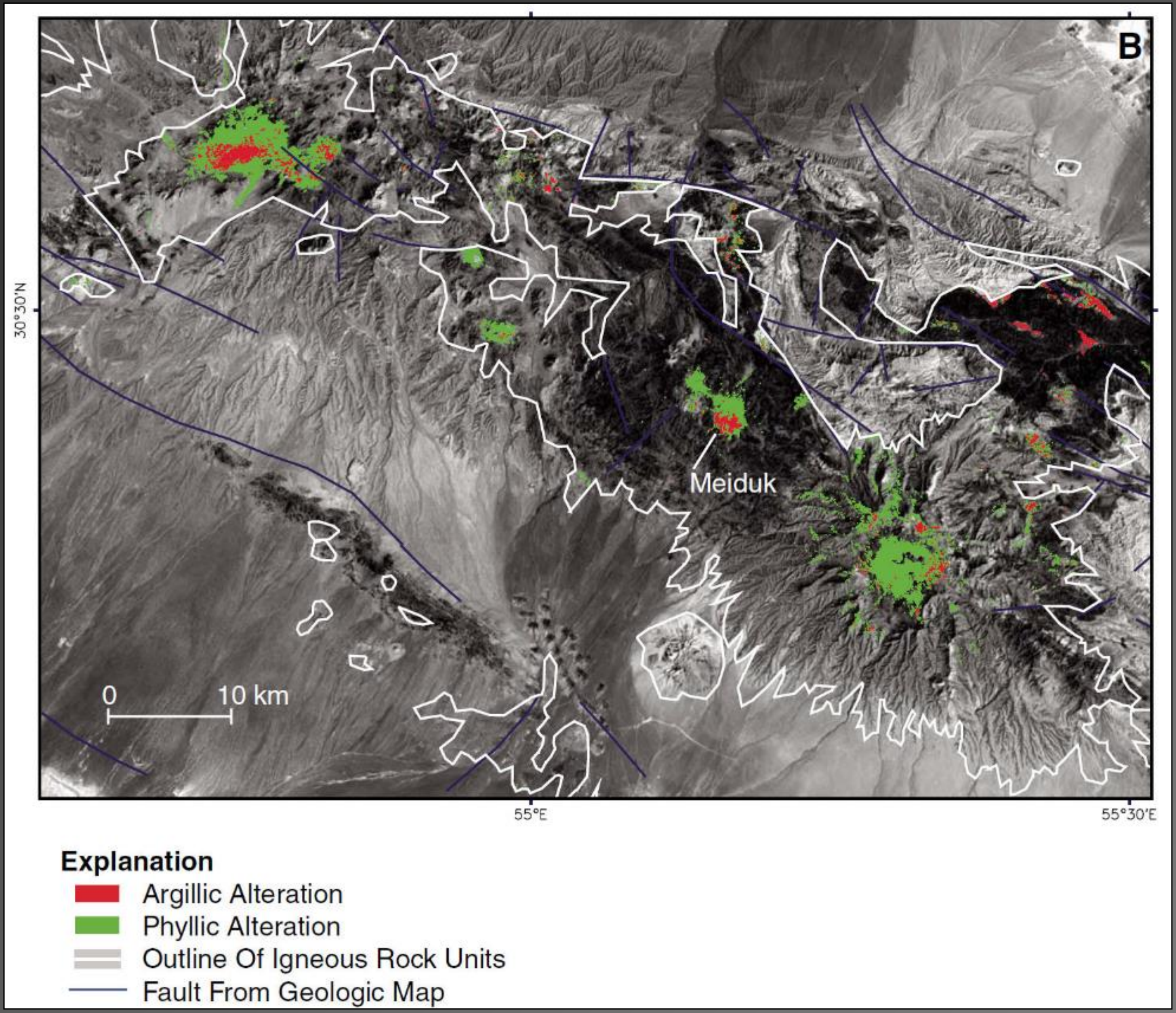
ASTER bands 3-2-1



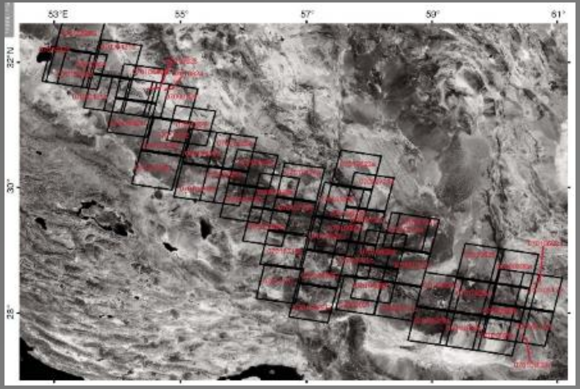
Number of methods giving anomalies



Regional Porphyry Copper Exploration



Mars and Rowan (2006) mosaicked 62 ASTER scenes in Zagros belt, Iran. Applying logical operators to map argillic and phyllic alteration, they "found" all of the known deposits, and identified dozens of potential porphyry copper targets.



Australian ASTER Geoscience Maps

ASTER Geoscience Map of Australia

ASTER Geoscience Map of Australia
Geoscience Product Notes
Data Download

Satellite ASTER Geoscience Map of Australia

Release 07.08.2012

The ASTER geoscience map of Australia will be publically released during the 34th International Geological Congress in Brisbane, Australia.

The Product

The ASTER geoscience map of Australia is a set of public, web-accessible digital geoscience products generated from satellite ASTER data.

ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) is a Japanese imaging instrument on board USA's TERRA satellite. The multispectral imaging sensor is the world's first and to date only "geoscience tuned" satellite Earth Observing System.

The Western Australian Centre of Excellence for 3D Mineral Mapping (C3DMM), led by CSIRO, developed new methods and software that transformed the raw ASTER data into a new suite of 17 geoscience products (e.g. Figure 1).

The ASTER geoscience maps of Australia represent the world's first continentscale maps of the Earth's surface mineralogy.

Product details

ASTER has 14 spectral bands spanning wavelengths sensitive to important rock forming minerals, including: Iron oxides; clays; carbonates; quartz; muscovite and chlorite.

Each ASTER image covers a 60 by 60 km area with individual pixel elements ranging from 15 to 90 m suitable for geoscience mapping from continent (1:2,500,000) down to mineral prospect (1:50,000) scale. The Australian mosaic is sourced from ~35,000 ASTER scenes with approximately 3500 used in the final mosaic.

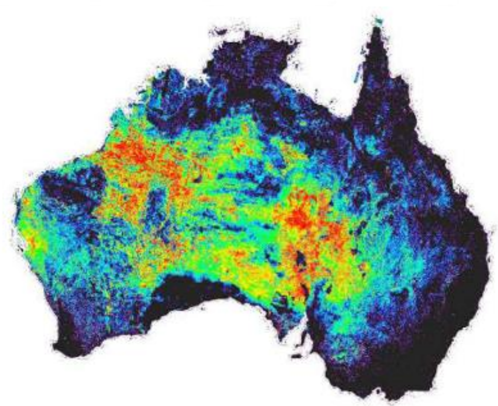


Figure 1: Satellite ASTER Geoscience map of iron oxide composition.

17 National Geoscience GIS-compatible maps; scalable, digital, "measured". (Cudahy, 2012)

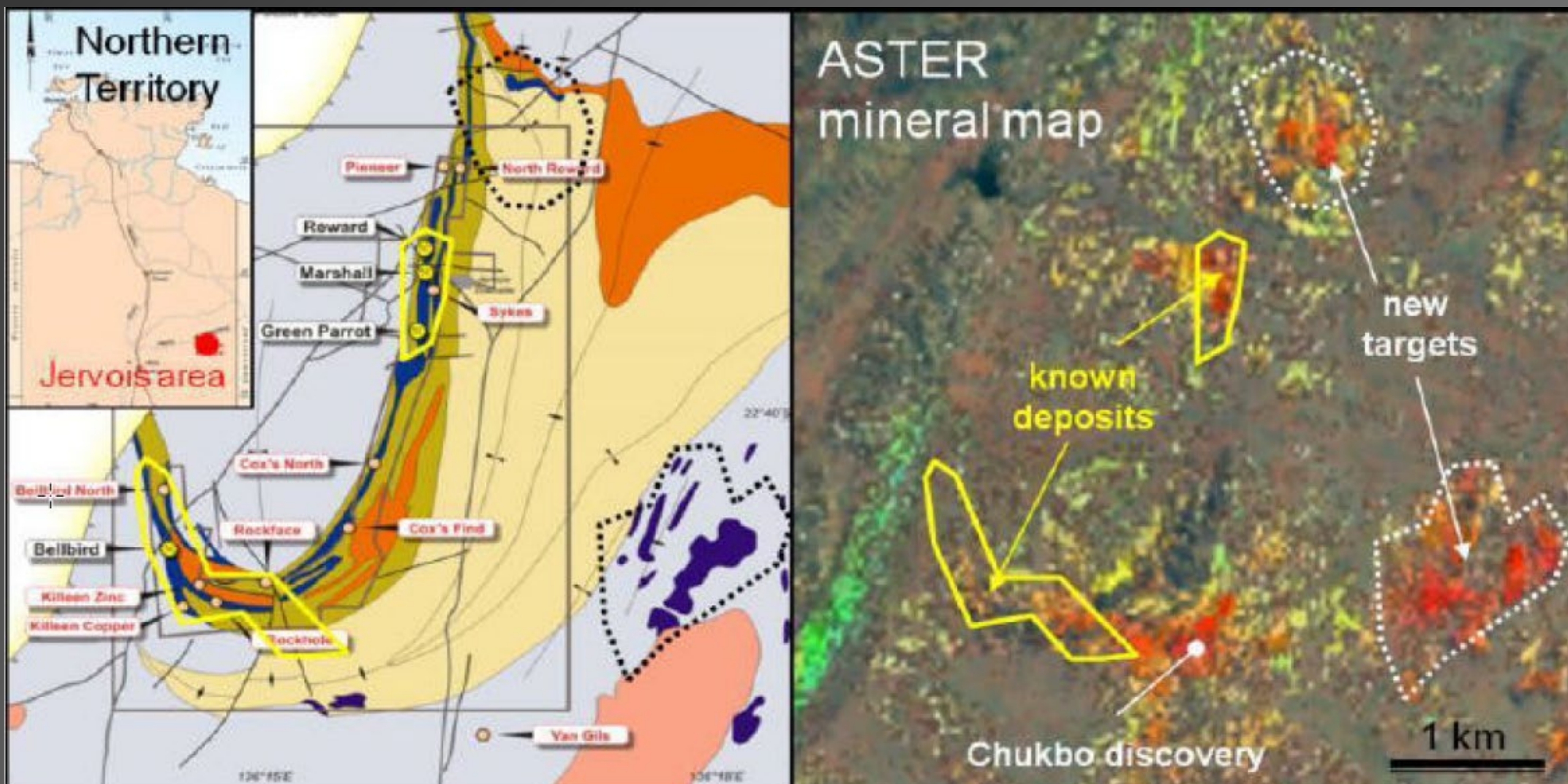
Fe-oxides, kaolinite, montmorillonite, vegetation cover, silica content, etc.

Created from ~3500 ASTER scenes; seamlessly mosaicked; 100 m resolution.

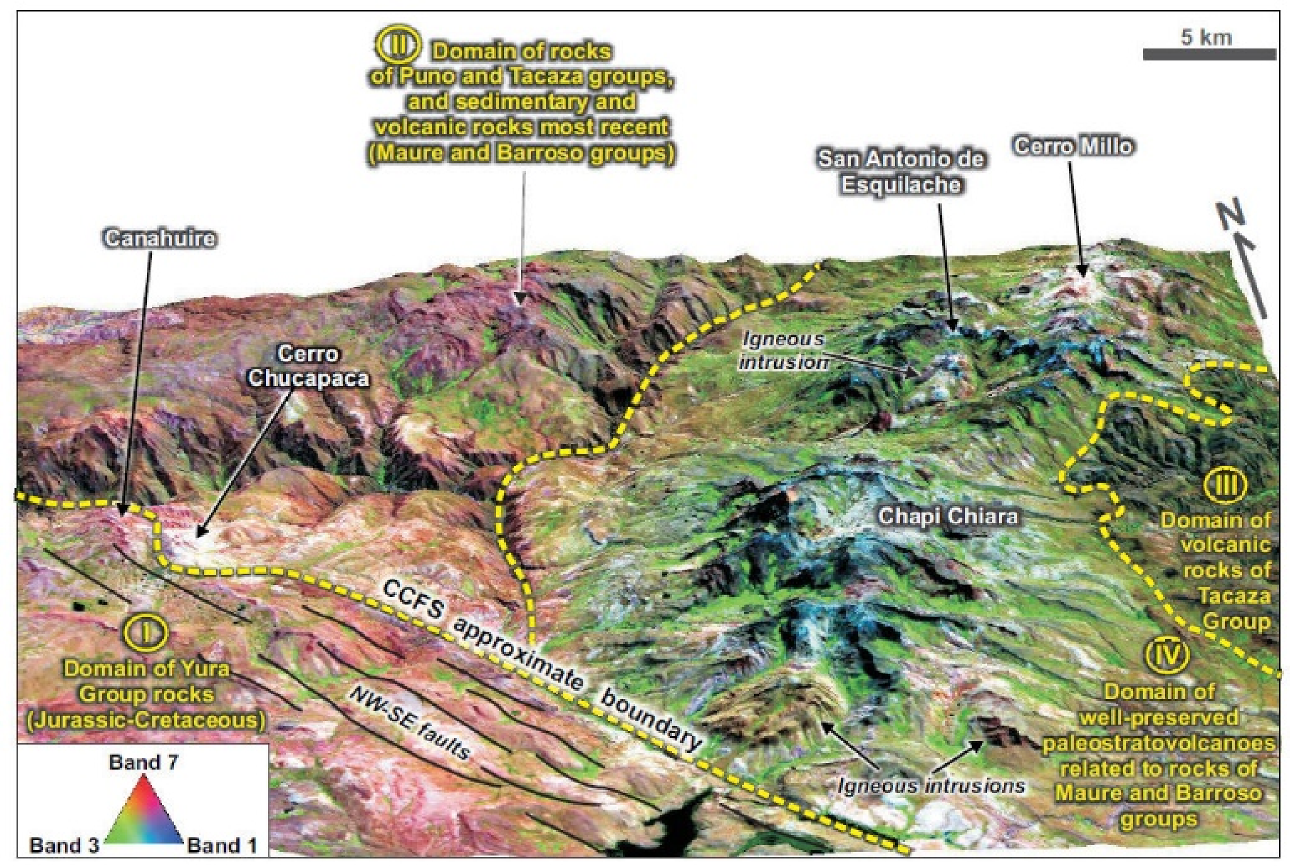
New mineral discoveries and environmental applications are a direct result.

Gold Discovery from Australian Geoscience Maps

Kentor Gold Ltd. announced Chukbo gold discovery based on phyllic and propyllitic alteration Geoscience maps (Wastac, 2014).



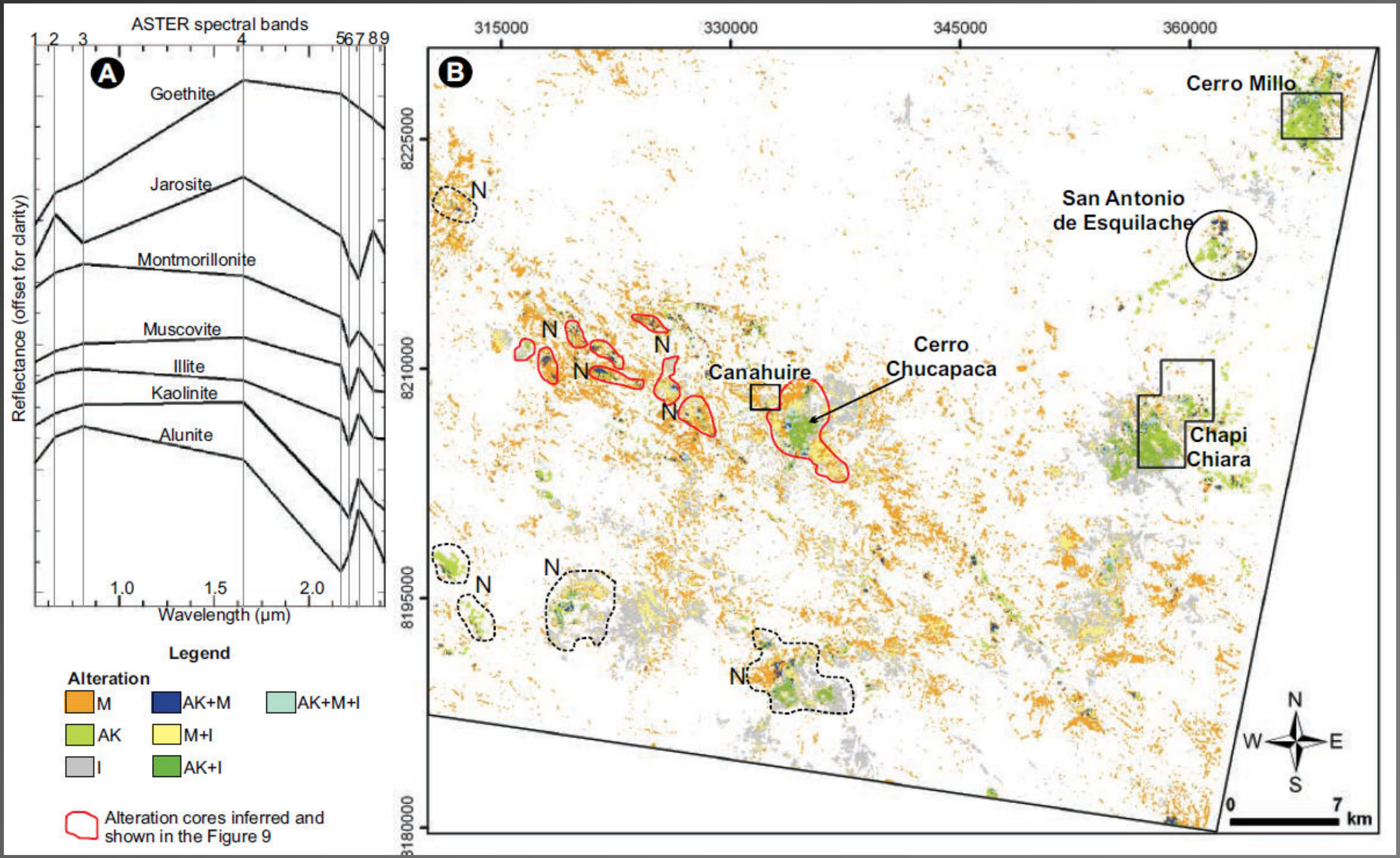
Alteration Mapping for Au-Ag Deposits



Carrino et al. (2015) used VNIR, SWIR and TIR data to map alteration and quartz and carbonate rocks in southern Peru. Analysis led to development of favorability model for epithermal Au-Ag deposits, based on zoning pattern and erosion level in paleostratovolcanoes.

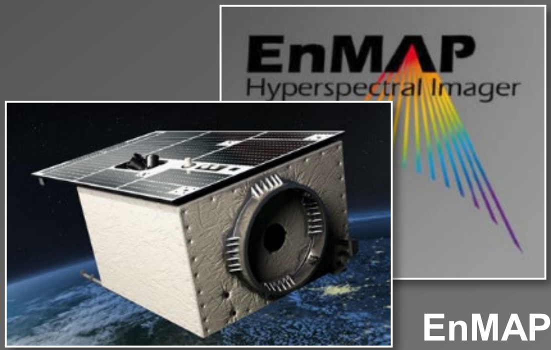
Alteration Mapping for Au-Ag Deposits

Alunite, kaolinite, montmorilonite, illite. N= new prospects



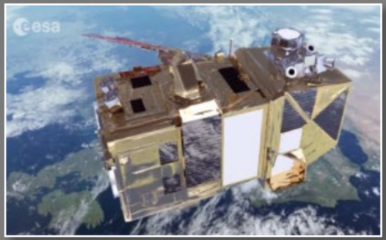
Recent and Future
State-Sponsored and (Commercial) Satellites

- **Sentinel-2 ESA**-13 bands – 2015 & 2017
- **DESIS Germany-**240 bands – 6/2018
- **ECOSTRESS** USA-5 TIR – 6/2018
- **Jilin-1 China** >220 bands – 1/2019
- **PRISMA Italy**-237 bands – 3/2019
- **HISUI Japan**-185 bands – 1/2020
- **ENMAP Germany**-262 bands – 12/2020
- **SHALOM Italy-Israel** >200 bands – 2021?
- **HYPXIM France** >200 bands - 2023?
- **SBG USA** >200 bands (8 TIR) - 2024?



EnMAP

PRISMA



ESA Sentinel-2

remote sensing

MDPI

Review

Twenty Years of ASTER Contributions to Lithologic Mapping and Mineral Exploration

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Abstract: The Advanced Spaceborne Thermal Emission and Reflection Radiometer is one of five instruments operating on the National Aeronautics and Space Administration (NASA) Terra platform. Launched in 1999, the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) has been acquiring optical data for 20 years. ASTER is a joint project between Japan's Ministry of Economy, Trade and Industry; and U.S. National Aeronautics and Space Administration. Numerous reports of geologic mapping and mineral exploration applications of ASTER data attest to the unique capabilities of the instrument. Until 2000, Landsat was the instrument of choice to provide surface composition information. Its scanners had two broadband short wave infrared (SWIR) bands and a single thermal infrared band. A single SWIR band amalgamated all diagnostic absorption features in the 2–2.5 micron wavelength region into a single band, providing no information on mineral composition. Clays, carbonates, and sulfates could only be detected as a single group. The single thermal infrared (TIR) band provided no information on silicate composition (felsic vs. mafic igneous rocks; quartz content of sedimentary rocks). Since 2000, all of these mineralogical distinctions, and more, could be accomplished due to ASTER's unique, high spatial resolution multispectral bands: six in the SWIR and five in the TIR. The data have sufficient information to provide good results using the simplest techniques, like band ratios, or more sophisticated analyses, like machine learning. A robust archive of images facilitated use of the data for global exploration and mapping.

Keywords: ASTER; mineral exploration; geologic mapping

1. Introduction

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) is one of five instruments on the U.S. Terra spaceborne platform (the other instruments are the Moderate Resolution Imaging Spectroradiometer (MODIS), Clouds and the Earth's Radiant Energy System (CERES), Multi-angle Imaging SpectroRadiometer (MISR), and Measurement of Pollution in the Troposphere (MOPITT)). Launched in December 1999, ASTER has been continuously acquiring image data for 20 years. ASTER is a joint project between Japan's Ministry of International Trade and Industry (MITI) (later changed to Ministry of economy, Trade and Industry (METI)) and the U.S. National Aeronautics and Space Administration (NASA). Japanese aerospace companies built the ASTER subsystems for METI; NASA provided the Terra platform and the Atlas 2AS launch vehicle. Both organizations are responsible for instrument calibration, scheduling, data archiving, processing, and distribution.

ASTER was conceived as a geologic mapping instrument. It was designed to provide several improvements over instruments existing at the time, like Landsat. The science team pushed for better spatial resolution, high spectral resolution short wave infrared (SWIR) bands, multispectral thermal

Remote Sens. 2019, *11*, 1394; doi:10.3390/rs11111394 www.mdpi.com/journal/remotesensing

Remote Sensing, **2019**, *11*, 1394; https://doi.org/10.3390/rs11111394.

Over 150 references compiled

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